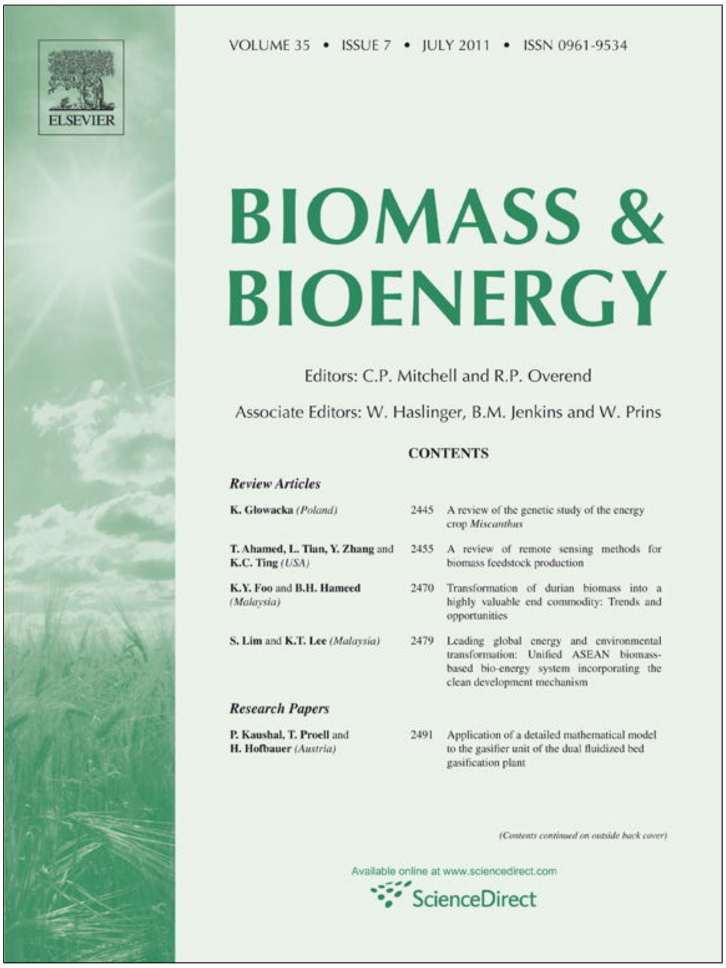
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Short communication

Ficus elastica – The Indian rubber tree – An underutilized promising multi-use species

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ABSTRACT

Ficus elastica known as the Indian rubber tree has a white, milky latex that is a source of natural rubber was analyzed for its phytochemicals as an intermediate energy source. The tree produces a high quantity of protein and oil (24.5 and 6.1% respectively). The polyphenol content was 4.2%, and hydrocarbon content was 2%. The gross calorific value of the plant sample was 28.7 MJ kg^{-1}, much higher than that of methanol (22.4 MJ kg^{-1}), but comparable to anthracite coal (29.7 MJ kg^{-1}). The gross calorific value of the oil fraction was 32.8 MJ kg^{-1}. This species also contains high levels of ortho-dihydroxy phenols which may be related to disease resistance to some pathogens. It also possesses compounds with antimicrobial activity and a range of pharmacological activities. *F. elastica* has several chemical constituents, other than rubber, which have potential uses and warrant further study.

1. Introduction

Growing plants as a renewable energy source is of increasing interest. The products obtained after processing are derivatives of the total biomass, and after it is separated from the cellulosic plant material, it can be used directly as diesel fuel in some cases, or it can be converted to a convenient liquid fuel, such as gasoline. Cultivation of plants which already produce hydrocarbon-like compounds is attractive because the conversion of this type of plant extract to energy is efficient, since the material is already in a reduced form.

A large number of plant species are capable of reducing carbon dioxide beyond carbohydrates to isoprenoids (C_5H_8) or other hydrocarbon-like compounds. Since *Ficus* species show an accumulation of potentially useful secondary products, it has been proposed for the study of its hydrocarbon production. *Ficus elastica* Roxb. has been identified as one of the few potential rubber producing crops [1].

F. elastica is a tree species belonging to the Moraceae family, and is known as the Indian and Assam rubber tree, whose white, milky latex is the source of natural rubber. It is adaptable for annual pollarding with also a potential fiber value and is distributed throughout Tamil Nadu. The tree grows profusely without any agronomic management and survives well under extreme environmental conditions, such as high temperature and limited water supply. It is propagated through stem cutting, but requires initial care to become established. Study on its growth characteristics especially on growth rates in different climatic conditions warrant further study.

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Polyisoprene is the main constituent of latex, which varies in quantity and weight from species to species. Low molecular weight natural rubber would be of interest as a plasticizing additive (processing aid) to rubber mixes, for making adhesive cements and if low enough in cost as hydrocarbon feed stocks [2]. A high calorific value of the hydrocarbon fraction suggests that the fraction may contain low molecular weight molecules. *F. elastica* latex consists of low molecular weight and short chain molecules. The quantity of rubber depends on the amount of metabolic substrates present which might be converted into rubber [3]. Latex of *F. elastica* has been reported to have low hypoallergenicity compared the *Heva brasiliensis* latex proteins and is a possible substitute for ameliorating *Heva* latex allergies [4].

Simple or complex phenols can be related to defense in plants [5], since these phenolics are high skin irritants and carcinogenic to animals. They also act as a gustatory repellent [6]. The considerable amount of ortho-dihydroxy phenols may be related to plant disease resistance, since they are poisonous and highly reactive with the amino acids of the pathogen, thus rendering them biologically inactive [7]. Herbivores graze *F. elastica* only a little and shy away. It possesses antimicrobial activity and the leaf extract is applied on skin infections, allergies of the skin, and as a diuretic [8]. Polyphenols are generally used to manufacture various adhesives, phenolic resins, and antioxidants [2,9,10].

Plant steroids and alkaloids are mostly poisonous even in minute quantities. They are often toxic to man and animals and have dramatic physiological activities, hence they are in wide use in medicine preparation. The species with these compounds exhibit a wide range of pharmacological activity like analgestic, emetic, vermifuge, diaphoretic, and antitumourous [11].

The objective of the study was to analyze the phytochemicals of the whole plant samples of *F. elastica* as an intermediate energy source.

2. Materials and methods

Whole plant samples were randomly collected (recent growth from the trees of *F. elastica*) including leaves, stems, seeds and any flowers if available which is referred to as "whole plant sample" during the spring season in and around the Virudhunagar Hindu Nadars Senthikumara Nadar (VHNSN) College campus from healthy plants of similar age (approximately 15 years old), height, and circumference growing in same agroclimatic zone. The VHNSN campus is located at 9.575169° N Lat, and 77.971693 °E Long in the city of Virudhunagar in the Tamil Nadu province of India. A minimum of 15 populations, each containing 10–20 plants with a total fresh weight of 2000–2500 g were combined into one sample for chemical analyses. The sample was sub-sampled twice. Recent growth from trees of *F. elastica* was collected and allowed to air dry in a protected sheltered area at ambient summer conditions. After thoroughly drying, the samples were ground in a Wiley mill equipped with a 1-mm diameter sieve.

Extractable fractions were removed from the plant biomass using propan-2-one followed by n-hexane in a Soxhlet apparatus for a minimum of 24 h per solvent. The propan-2-one extracts were allowed to dry at 45 °C for 48h and partitioned between n-hexane and aqueous ethanol (water:ethanol, 1:7) to obtain fractions 'oil' and 'polyphenol', which were oven dried at 45 °C for 48 h and weighed for yield. The 'hydrocarbon' fraction was also oven dried at 40 °C for 36 h and weighed for yield after removal of the n-hexane [9,10].

2.1. Analytical analysis

Ground sub-samples were analyzed for ash and lignin content [12]. Protein content was determined by the Kjeldahl method [13]. Nuclear Magnetic Resonance Spectra (NMR) spectra of hydrocarbon fractions were recorded using a Bruker AC 300 F NMR spectrometer (300 MHz) with tetramethylsilane (TMS) as the internal standard and (deuterochloroform) $CDCl_3$ as the solvent. Gross calorific values of the plant sub-samples, oil and hydrocarbon fractions, were determined using a Toshniwal Model cc. O. 1, Bomb Calorimeter [14]. Primary and secondary metabolites of the plant sample were estimated using a spectrophotometer. Carbohydrate were determined using the phenol-sulphuric acid method [15,16]. Total phenols were determined using the Folin–Ciocalteau method [17], and ortho-dihydroxy phenols (OD phenols) [18]. Phytochemicals namely steroids, flavonoids, and alkaloids were tested either for their presence or absence [19].

2.2. Statistical analysis

Three replications of each sub-sample were evaluated for extraction of chemical constituents, protein, ash content, and gross calorific value. Values in Table 1 are the means of three replications, ± standard deviation (S.D.).

3. Results and discussion

In the present study, *F. elastica* had a substantial amount of both protein with 24.5% and an oil content of 6.1%. The tree species yielded 4.2% polyphenol, and 2% hydrocarbon. Since the species yields a high quantity of protein, it has the potential of providing a protein rich feed for cattle [20]. If properly handled and all antinutritional factors are removed that complicate its usage [21], such as alkaloids that pose threat to palatability, and glucosides viz. saponins [22], it could be used as animal feed.

The extracted oil sample was slightly gummy, and viscous in nature at room temperature. If properly treated to reduce its viscosity [23], it could be a promising alternative to conventional oils. Oil in this species is either a major component of latex or distributed throughout the plant body. The milky exudates of *F. elastica* contain about 30% caoutchouc (rubber). The leaves contain polyphenols viz. ficaprenol-10, -11 and -12, probably same as castaprenol-10, -11, and -12 [1]. Determination of the annual latex yield and processing required still need to be studied further.

3.1. Gross calorific values

Gross calorific value of the plant samples, oil, and hydrocarbon fractions are shown in Table 1. The potential of the

Table 1 – Calorific values, ash, and lignin values of extractables of *Ficus elastica*.

Source	Gross calorific value[a] ($MJkg^{-1}$)	Low calorific value[a] ($MJkg^{-1}$)	Ash (%)	Lignin (%)
Plant sample	28.7 ± 0.10[b]	27.4 ± 0.10	0.8 ± 0.10	47.1 ± 0.25
Oil fraction	32.8 ± 0.10	31.1 ± 0.10	–	–
Hydrocarbon fraction	41.2 ± 0.10	39.1 ± 0.10	–	–

a Values expressed on a dry weight basis.
b Values are means of three replicates, ±S.D.

plant sample as a promising intermediate energy source is also confirmed by the quantity of ash and lignin. The samples contained 0.8% ash, and 47.1% lignin. High ash content had a negative effect on the calorific value in two milkweed species [24]. The high gross calorific value can also be attributed to the high percentage of oil, polyphenol, and hydrocarbon present in the tissues.

The gross calorific value of the oil fraction was 32.8 MJ kg^{-1} which is higher than that of anthracite coal 29.7 MJ kg^{-1}. The hydrocarbon fraction of *F. elastica* had a high gross calorific value comparable to that of Mexican fuel oil. Indian rubber tree samples with hydrocarbon yields of 2%, and gross calorific value of 37.7 MJ kg^{-1} could be a promising candidate for future use and warrants further detailed study such as climatic range yield, responses to rain fall, cost of separating "product" from the cellulosic material, and cost of producing wood.

3.2. *NMR spectroscopy*

The Nuclear Magnetic Resonance spectra revealed that the hydrocarbon fraction have cis-methyl with 1,2 moiety + methylene nearly trans [25,26]. These low molecular weight and short chain molecules as trans polyisoprene (gutta) can have large-scale application as both additional thermoplastics and thermosetting resins [27].

3.3. *Phytochemical properties*

The qualitative tests revealed that the whole plant sample contained steroids and alkaloids. The plant samples contained 1.1% carbohydrates, 1.1% total phenols, and 1.3% OD phenols.

4. Conclusions

F. elastica is a potential alternative multi-use species because of its hydrocarbon production (2.0%) and high calorific value (28.7 MJ kg^{-1}). It also has a high protein and oil yield. The low ash content of the Indian rubber tree has a positive effect on the high gross calorific value. *F. elastica* has several chemical constituents, other than rubber, which have potential uses and warrants further study.

REFERENCES

[1] Ram RP, Mehrotra BN. In: Ram RP, editor. Compendium of Indian medicinal plants, Vol. 1. New Delhi/Lucknow: Central Drug Research Institute/Publications and Information Directorate; 1995.
[2] Buchanan RA, Otey FH, Bagby MO. Botanochemicals. In: Swain T, Kleiman R, editors. Recent advances in phytochemistry, Vol. 14. New York: Plenum Press; 1980. p. 1–22.
[3] Shukla OP, Krishnamurthi CR. The biochemistry of plant latex. J Sci Ind Res 1971;30:640–62.
[4] Siler D, Cornish K. Hypoallergenicity of guayule rubber particle proteins compared to *Heva* latex proteins. Ind Crops Prod 1994;2(4):307–13.
[5] Levin DA. The role of trichome in plant defense. Quart Rev Biol 1973;48:3–15.
[6] Peterson RL, Vermeer J. Histochemistry of trichomes. In: Rodriguez E, Healey PL, Mehta IJ, editors. Biology and chemistry of plant trichomes. London: Plenum Press; 1984. p. 71–93.
[7] Goodman RN, Kiraly Z, Zaitlin M. The biochemistry and physiology of infections and plant diseases. Melbourne: Van Nostrand; 1967.
[8] Agarwal VS. Drug plants of India, Vol. I. India: Kalyani Publishers; 1997.
[9] Buchanan RA, Cull IM, Otey FH, Russel CR. Hydrocarbon and rubber producing crops: evaluation of U.S. plant species. Econ Bot 1978;32:131–45.
[10] Buchanan RA, Cull IM, Otey FH, Russel CR. Hydrocarbon and rubber producing crops: evaluation of U.S. plant species. Econ Bot 1978;32:146–53.
[11] Marimuthu M. Chemical analysis of laticiferous plants. Ph.D. thesis. India: Sardar Patel University, Anand, Gujarat; 1988.
[12] Goering HK, Van Soest PJ. Forage fiber analysis. In: Agri Handbook, vol. 379. Washington, DC: USDA-ARS; 1970.
[13] AOAC. Official methods of analysis. 13th ed. Washington, DC: Association of Official Analytical Chemists; 1980.
[14] Anonymous. Oxygen bomb calorimetry and combustion methods. Technical Manual no.153. Moline, IL: Parr Instrument Co.; 1966.
[15] Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F. A calorimetric method for determination of sugars. Nature 1951;168:167–8.
[16] Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F. A calorimetric method for determination of sugars and related substances. Anal Chem 1956;28:351–6.
[17] Bray HG, Thorpe WV. Analysis of phenolic compounds of interest in metabolism. Method Biochem Anal 1954;1:27–52.
[18] Arnow LE. Calorimetric determination of the components of 2,4-dihydroxy-phenylalanine tyrosine mixtures. J Biol Chem 1937;118:531–7.
[19] Gibbs RD. Chemotaxonomy of flowering plants. London: McGill Queens University Press; 1974.
[20] Pirie NW. Food protein sources. New York: Cambridge University Press; 1975.
[21] Shirley RL. Nitrogen and energy nutrition of ruminants: animal feeding and nutrition. New York: Academic Press; 1986.
[22] Kellems RO, Church DC. Livestock feeds and feeding. Upper Saddle River, New York: Prentice-Hall; 1988.

[23] Bagby MO. Products from vegetable oils: two examples. In: Fuller G, Mckeon JA, Bills DD, editors. Agricultural materials as renewable resources. ACS Sym Ser, vol. 647; 1996. p. 248–57.
[24] Van Emon J, Seiber JN. Chemical constituents and energy content of two milkweeds, *Asclepias curassavica* and *A. speciosa*. Econ Bot 1985;39:47–55.
[25] Chen HY. Nuclear magnetic resonance study of butadiene-isoprene-polymers. Anal Chem 1962;34:1134–6.
[26] Bovey FA. High resolution of macromolecules. New York: Academic Press; 1972.
[27] Kramer PJ. Physiology of woody plants. New York: Academic Press; 1979.